Comments of

The Ultra Wide Band (UWB) Alliance

Before

The Federal Communications Commission

Notice of Inquiry on Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz.

ET Docket No. 18–295
GN Docket No. 17-183
FCC 18–147

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About the UWB Alliance

The Ultra Wide Band Alliance ("UWB Alliance") is a global not-for-profit organization that works to collectively establish ultra-wideband (UWB) technology as an open-standards industry. A non-profit coalition made up of vendors that either design, manufacture, or sell products that use ultra-wideband technology, the UWB Alliance aims to promote and protect the current allocation of bandwidth as well as promote the continuing globalization of the technology. In addition, the Alliance is promoting and assuring interoperability through its work with Standards Development Organizations (SDOs) such as the IEEE and ETSI and then working with members to define upper layers and testing to assure compliance.

The UWB Ecosystem

The UWB ecosystem includes a wide range of applications varying from consumer items such as secure wireless vehicle key fobs to tool tracking for aircraft manufacturing. The current FCC regulations allow both UWB (15.517 – 15.519) and Wideband (15.250) devices to coexist well with other spectrum users, both licensed and license-exempt; as a result, the FCC has stimulated innovation in UWB applications, such as: Smartphone ecosystems; Consumer home automation, including automated lawnmowers; Sports tracking and analytics, including every NFL stadium; Secure automated vehicle lock/unlock; Aviation manufacture/tool tracking, including throughout 30 buildings across Boeing's four campuses; Wireless USB; and Automated automotive manufacturing. The IEEE projects the expanding UWB market will exceed 3.1 billion devices by 2025. But most importantly UWB has only begun to evolve technically, including expanding device ranges up to 1,000 feet and techniques that will offer equivalent Wi-Fi services, but at power levels that won't threaten other users of the band.

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1 Introduction

The UWB Alliance commends the Commission on efforts to enable flexible use of spectrum and in particular enabling greater license exempt use. Historically, license exempt allocations have promoted technological innovation for a diversity of users and uses. To fully realize the value of spectrum, rules must enable a diverse set of technologies to be developed to address an ever growing diversity in users and user needs. No single technology is ideal for all needs and effective sharing of spectrum among different technologies suited to different uses is essential to achieving maximum value.

The UWB Alliance endorses efforts to find ways to expand Wireless LAN (WLAN) access to serve a greater number of users. WLAN is an essential technology in connecting consumers to the internet, the "last feet" connection for many if not most internet users. WLAN is not the only technology that provides value through licensed exempt uses and there are a great many applications with needs that are better met with different technologies. Achieving the most efficiency and value from spectrum requires the ability to fit the best technology for a given use. Historically, license exempt rules that have been most successful at enabling technology innovation and the greatest public benefit have been technology agnostic.

The current proposed rules raise serious concerns that operation under the proposed rules may cause much more interference than anticipated with consumer, commercial, medical, and scientific applications in the 6 GHz spectrum.

The rules seem tailored for the WLAN architecture and technologies specifically, and disadvantage other established technologies that currently utilize the subject bands providing proven coexistence with other spectrum users. These other users include both licensed and unlicensed users such as those complying with IEEE 802.15.4 standards established as far back a 2007. The conclusion by the Commission that such WLAN operation will not harm incumbent users – both licensed and licensed exempt – depend on assumptions that are not captured in the proposed rules. Our goal is mutual coexistence, to achieve the greatest possible value from the spectrum.

2 Executive summary

In these comments, the UWB Alliance presents changes to the proposed rules which will promote more efficient and effective use of the spectrum. Our suggestions satisfy the need for greater WLAN access while also promoting sharing of the spectrum with other equally important and valuable uses. We have focused on methods that benefit all users, including WLAN.

Specifically we are asking the Commission to consider modifying the proposed rules as follows for all applications of the proposed rules:

1. Authorize new unlicensed broadband at the proposed standard power levels only in the sub-band 5.925 - 6.1 GHz (the lower 175 MHz of the proposed U-NII-5 band), and
2. Specify out of band emissions not to exceed -61 dBm/MHz;

<u>OR</u>

1. Include maximum transmit duty cycle requirements for use of standard-power operation, and
2. Specify lower power levels for the remainder of the band (6.1 to 7.125 GHz).

For commercial applications we suggest the following:

1. Apply automated frequency control (AFC) in all of the proposed new U-NII bands for standard power operation;
2. Augment AFC with the concept of a ‘beacon fence’ for commercial users to inform other unlicensed devices not to transmit in the area; and
3. Include a requirement that new unlicensed broadband devices listen for the ‘beacon fence’ signal and if detected, avoid transmission in the indicated sub-bands.

Allocation in the sub-band 5.925 - 6.1 GHz opens 175 MHz of new spectrum allocation for conventional broadband implementations such as WLAN, exceeding the mandate of the MOBILE NOW Act (Pub. L. 115-141.). Specifying lower power levels for the remainder of the band will inspire innovation and conserve use of the spectrum, continue the proven protection of incumbent fixed satellite service (FSS), fixed service (FS), Scientific, and UWB users provided by the existing rule power limits.

The proposed NPRM limit for out of band emissions (OOBE) is substantially higher than the intentional limit of -41.3 dBm/MHz of the existing UWB and Wideband rules. The current rules have proven sufficient protection for incumbent licensed users, as well as excellent sharing of multiple licensed exempt technologies. The OOBE of -27 dBm/MHz proposed in the NPRM substantially increases the risk of interference with licensed services in adjacent bands. Our proposed out of band limit of -61 dBm/MHz protects existing services and is practical to achieve with best practices in design and engineering.

The duty cycle suggestion is based upon both the assumptions stated by WLAN advocates and the study commissioned by the Wi-Fi Alliance as well as studies done independently by the UWB Alliance. Given that the 0.5% duty cycle limit exceeds what WLAN proponents used in their RKF study, we suggest this limit is included in the regulations. We propose to define the duty cycle over 1 second intervals. That will maximize the chances for gaps during which other transmissions can take place and enable practical verification of the requirement.

These suggestions will yield higher spectral re-use and overall greater capacity in the band which is essential given the high demand. This benefits all users including many WLAN as in many scenarios WLAN performance is interference limited.

The commission proposes AFC to protect some incumbent users which are in fixed well known locations, and the UWB Alliance endorses the concept. We favor a centralized AFC approach. We also recognize that for many incumbent users, AFC is not sufficient to provide necessary coordination. It may also be impractical to implement in some types of applications and/or devices. We propose to address these limitations by augmenting AFC with a method in which licensed exempt devices can independently share the spectrum effectively, by use of a registered beaconing device that advertises via a broadcast signal the presence of commercial users and informs other devices such as WLAN access points to avoid transmission in the area. This enables new unlicensed devices to detect and avoid causing harmful interference.

3 Background

3.1 Spectrum crisis – a crisis of choice

There are multiple factors which contribute to the 'spectrum crisis' noted in the NPRM. The need can be summarized as an increase in the quantity of users and data needing to be transferred within any given period of time. When the density of devices and data is small, there is no crisis: existing allocations are enough. The perceived shortage occurs when there are many user devices contending for the same spectrum in the same place and time. Increasing available bandwidth provides temporary relief, but efficient use of the spectrum is the key to maximizing utilization of this finite resource.

Although the technologies underlying WLAN are not inherently inefficient, it is common that an Access Point (AP) or Station (STA) creates a much larger spectrum footprint than is needed. There are multiple dimensions of performance improvement available to WLAN operation which are not utilized but are supported by the underlying technologies and even by many existing implementations (chipsets, etc.). In particular, the expressed need for high power transmissions is contradictory to achieving high reuse factors required to support high density usage scenarios.

In a high-density environment, performance and capacity becomes interference limited. Use of transmit power in excess of that needed to achieve the required link margin is detrimental to performance and reliability in a network because the interference footprint of each device is far greater than necessary. This is a significant contributor WLAN capacity limitation. The 'win-win' in reducing interference footprint is that it increases spectrum capacity for all users, including WLAN.

In radios the adage 'less is more' is very frequently true: less power increases performance. The proposed rules could encourage higher spectral reuse by providing incentives for lower power operation and intelligent management of RF footprint.

Spectral reuse is key to getting the most out of the spectrum. Achieving high reuse for multiple purposes requires coexistence of different technologies and creating a minimal interference footprint per device. Sharing and coexistence are essential to meet the future needs of WLAN as well as other spectrum users.

3.2 UWB and Wideband: Innovation and Unique Capabilities.

The Commission's rules enabling UWB and Wideband operation (Subpart F and 15.250) have been successful in promoting innovation. UWB radios have been applied to a diverse set of applications where the unique characteristics and capabilities have advantages over carrier-based technologies. Operating under the existing rules, UWB and Wideband systems have proven coexistence with all current users in the 6 to 7 GHz bands.

UWB provides for extremely precise, near instantaneous ranging (distance determination) dynamic tracking of people and things and detection/sensing of material and objects in a variety of environments. The UWB signal structure and modulation techniques require less power than traditional carrier-based radio, which allows UWB devices to provide multi-year operation in devices powered by small coin cell batteries. This makes UWB suitable for very small form factor devices, (e.g., the NFL is using devices that fit under the shoulder pads of players and device installed inside footballs). These provide instantaneous detection of motion and precise location determination in real time.

Precise ranging with traditional carrier-based signals requires much longer integration periods and so cannot provide the near instantaneous performance of UWB. The ability to instantaneously detect and track motion has many applications in advanced Internet of Things (IoT).

UWB has very high immunity to multi-path fading, eliminating problems associated with multi-path without high power or added complexity. This benefits applications where latency is critical and retransmission is not an option.

Very low power transmissions provide for very high device density and high spectral re-use. Additionally, UWB developers have applied multiple innovative methods to enable simultaneous operation of many devices in the same radio sphere of influence (SoI), further enhancing spectral re-use. The low power UWB signal is highly resistant to hijacking and hacking.

In some applications such as real-time full frequency audio for entertainment and gaming, these characteristics enable solutions that are impossible using traditional radio techniques. In the explosion of IoT, there are a great many 'things' for which UWB is the most suitable technology.

These characteristics match UWB to applications not well addressed with conventional technologies.

3.3 Diversity of applications and markets

UWB devices have been used in products for a variety of markets and applications. There are standards-conformant products based upon IEEE Std 802.15.4 as well as proprietary protocols. Large deployments exist in consumer and commercial markets. UWB is widely used and currently application is growing rapidly as manufacturers of high-volume consumer products are capitalizing on the unique capabilities of UWB.

UWB products for consumers currently available include:

- Automotive radar ranging systems
- Baby, sleep apnea, and pulse monitoring
- Radars for wall exploocration
- Robotic lawn mower for sale this year
- Fall monitoring
- Universal IoT Remote

Some commercial applications include:

- Professional audio
- Sports tracking (NFL)
- Industrial asset tracking
- Automotive and industrial production automation
- Stock animal health and tracking
- Tank level radar sensing
- Airport baggage handling
- Bus and train control and communication

Many of these applications provide for safety and welfare of users and represent a significant economic impact.

There are many applications emerging with expansive growth and accelerating interest for high volume uses. The uptick in activity is reflected in new standards activity: the IEEE 802.15 working group has a new project underway amending the IEEE Std 802.15.4 MAC and UWB Physical Layers (Task Group 802.15.4z) specifically to address the needs of consumer products, including highly secure wireless entry for vehicles and homes, and use in smartphone ecosystems. Participants in TG4z include the largest manufacturers of smartphones and related devices; UWB is and will be used in devices such as watches, secure automated entry, fitness trackers, automate “follow-me” uses, pet tracking and so on. Some key emerging applications seeing wide and/or accelerated adoption include:

- Secure access, Individual identification and human presence detection
- Applications with high density of devices in a small space, such as smart phone and personal devices
- Applications where size and energy consumption are critical factors
- Application of precise (sub-centimeter) precision is required dynamically, which is enabling new kinds of personal devices and enhancing human interaction with ‘things’ in many consumer and IoT applications.

In summary, UWB is already big and about to get much bigger.

3.4 Value of markets and growth potential

There are high-volume (10s of million units per year) applications currently using UWB. UWB meets the unique use-case requirements for low-energy at a cost-level well within acceptance for high-volume consumer applications. Multiple vendors have developed low-cost UWB SMOS system-on-a-chip (SoC) solutions enabling high growth and massive interest for uses where there are no comparable alternative solutions.

The sales of these SoCs is measured in millions, with one vendor alone responsible for greater than 5 million units in sales. These SoCs are part of an ecosystem, so the economic impact of obviating the operation of installed UWB devices is vastly beyond the value of the SoC chips. The UWB ecosystem extends through the entire value chain of industries including multiple auto manufacturers with assembly plants throughout the USA and the world, aircraft manufacturers tracking tools at plants employing more than 36,000 USA based associates.

Additionally, a growing population of vehicles are being equipped with high security UWB wireless entry systems. Investments have been made by an expanding number of manufacturers, with 100s of thousands of vehicles equipped with the technology having already been deployed by one of the industry leaders.

Wireless microphones use UWB technology for its real-time full audio range are used daily in the sports broadcasting industry. The NFL uses UWB real-time tracking of the players and footballs at every game in every stadium in the USA. The tracking systems are also used in practice fields throughout the USA.

As IoT explodes in usages, UWB is the optimum technology for many ‘things,’ accelerating the overall growth of IoT. The short burst messages specified in standards such IEEE Std 802.15.4, ISO 24730-61 and ISO 24730-62 are optimized for high spectral density and precise ranging capabilities. No other technology offers the same ranging and locating accuracy to within an order of magnitude of UWB.

These attributes combined with the tiny amount of power required to transmit a UWB message make it the best technology for many existing and emerging IoT applications.

The desirability of these technical properties and their applicability to IoT is borne out by the investments being made to the next generation of UWB. The current IEEE 802.15 4z Task Group is hosting the largest participation of any task group a within the 802.15 Working Group with bi-monthly attendance from over 40 engineers from all over the world. These engineers are representing some of the largest volume technical product manufacturers in the world. Chip vendors from multiple companies are also in attendance and have merged their technological contributions in order to provide the basis for interoperability to enable the growth of chips sold to reach into the billions by 2025.

4 Comments on AFC

The Commission seeks comments on many aspects of AFC. The Commission specifically asks if there are alternate methods to assure protection of incumbent services. The UWB alliance endorses the use of AFC while acknowledging the limitations of AFC.

<u>AFC in all new U-NII sub-bands</u>: We recommend that AFC be applied to the entire proposed band. The benefit of AFC apply equally across the entire 5.925 to 7.125 GHz band.

<u>Expanding AFC to include known deployments of other systems (coordinated sharing)</u>: We recommend that AFC system provides the ability to register commercial/industrial uses of licensed exempt devices at known locations which may be negatively impacted by high powered unlicensed operations. Examples include where UWB is being used in factory applications, at sporting events and media production studios. Coordination between unlicensed users can provide greater utility from the band and this increases the utility of AFC.

<u>Centralized AFC database</u>: We suggest that a centralized approach be used to increase the currency and consistency of AFC data. Technical requirements for AFC services need to include the ability to update information quickly. Some incumbent operations are stationary when in use but transitory in nature, for example, mobile microwave links used in electronic news gathering.

There are situations where AFC is not practical or is not sufficient to protect incumbents and ensure efficient use of the spectrum.

<u>Alternative to AFC</u>: We note that many scenarios for WLAN do not require power levels near what is authorized by the proposed rules and in fact would perform better at low power. For example, the typical mobile hotspot is used to connect a few devices within a foot or less of each other (e.g., on the same table). It is also common to see multiple mobile hotspots forming multiple networks in the same room. In these scenarios, lower power reduces the interference of adjacent networks and users, improving the performance for WLAN users, as well as reduce potential interference to other users.

<u>Augment AFC</u>: An active detection scheme can augment AFC and provide additional capability when the AFC database is not available or where incomplete. The ‘beacon fence’ idea would be executed like this: a device (the beacon) that broadcasts an information signal that is detectable by any potential unlicensed user of the band. The beaconing device would be registered with the FCC. The high power unlicensed broadband device would be required to listen for the detectable information signal prior to transmitting or allowing transmission on in the 6 GHz band.

5 Comments on Mobile Hotspots

5.1 Very low power mobile hotspots

In the Commission's proposed rules, operation of access points in moving vehicles is prohibited. The UWB alliance questions the practicality of this restriction as to how manufacturers of mobile consumer devices will prevent users from turning on mobile access points (a.k.a. mobile hotspots) in the prohibited vehicles. We also note that the proposed rules do not explicitly prevent use of mobile hotspots in other situations in which operation at the standard power levels permitted in the proposed rules would be harmful to other users, as well as unnecessary for the intended operation of the access point.

Acknowledging that users are unpredictable, a more practical approach is to allow low power mobile hotspots based on typical use case. The typical use case is forming a small network with the AP and STAs within a foot or two of each other, likely on the same table or desk, with potentially many mobile APs enabled in the same room or small area. Constrained power can avoid interference and still do the job of closing the link between devices at a few feet. In the typical mobile application, high power is not needed and in fact counter to best performance.

The same approach can address a related issue with the prohibition on outdoor APs. It is hard to detect outdoor vs indoor reliably in a mobile device and harder to predict the behavior and movement of a user.

6 Coexistence analysis

The UWB Alliance believes that good coexistence between different systems is critical to achieve full value from the spectrum allocation. We note that good coexistence increases performance for all systems, and need not disadvantage one technology over others. Coexistence strategies can enhance spectral reuse and reduce impairments to performance caused by interference. Spectrum efficiency considerations must include both the ability to support a high density of devices in a physical space and the diversity of uses that can be achieved.

This section presents analysis of the coexistence situation with respect to proposed new WLAN operations, a primary focus of the NPRM, and devices operating under the existing Wideband and UWB rules.

6.1 Coexistence impact studies

This section presents results of simulation studies that consider the impact of the potential introduction of WLAN systems in the 6 GHz band on existing UWB systems.

The WLAN deployment assumptions are based on those listed in the RKF study. However, as many of these assumptions, in particular with regards to market share, duty cycle and transmit power control, are not included in the regulations as currently proposed, alternative sets of assumptions are also evaluated.

6.2 WLAN deployment assumptions

6.2.1 RKF-like assumptions

In the first instance, the WLAN deployment characteristics from the RKF study[1] are followed. However, whereas the RKF study appears to have a time horizon of 2025 and therefore considers a market share of 45% for 6 GHz enabled WLAN, compatibility studies should give confidence to existing users much longer in the future and a market share of 95% 6 GHz enabled WLAN is therefore assumed.

For completeness, the relevant assumptions are listed below.

Each person is assumed to have 10 WLAN devices. Ten percent are high activity devices, with a duty cycle of 0.44%, while the remaining ninety percent of devices are low activity devices with a duty cycle of 0.00022%.

As discussed above, 95% of WLAN devices are assumed to be 6 GHz enabled. Based on the ratio of available bandwidth, 68% of those devices are assumed to be actually operating in the 6 GHz band.

Only 2% of the devices operate outdoors, with the remaining 98% used indoors.

The WLAN power distribution was modified slightly to take into account that the proposed rules don't allow 4 W transmissions. It was therefore assumed that these transmissions will take place at 1 W. Based on table 3-7 and 3-8 of the original RKF report, the power distributions are shown in Table 1.

EIRP (mW)	1000	250	100	50	13	1
Indoor	0.67%+042%	10.39%	6.49%	24.64%	51.84%	5.56%
Outdoor	2.83%+2.02%	9.45%	9%	32.13%	41.99%	2.58%

Table 1: Power Distributions from RKF

In the frequency bands where the regulations don’t allow 1000 mW transmissions, it is assumed these will take place at 250 mW instead.

The RKF study assumes the WLAN devices will operate in compliance with IEEE 802.11 in bandwidths of 20, 40, 80, and 160 MHz. The probability of a certain bandwidth being used is given in Table 3-9 of the RKF report, which is reproduced here for completeness in Table 2.

Bandwidth	20 MHz	40 MHz	80 MHz	160 MHz
Percentage	10%	10%	50%	30%

Table 2: Bandwidth Probability

6.2.2 Other assumptions

While the RKF assumptions are based on current IEEE 802.11 deployment scenarios, other WLAN systems and deployment scenarios are possible under the proposed regulations. In particular, the regulations don’t restrict transmit power and duty cycle.

The indoor/outdoor ratio and bandwidth distribution of the RKF studies have been preserved. It is currently not known whether these are representative of future applications. For example, one could easily imagine that augmented reality applications are more likely to be used outdoors and that as spectrum demand and modulation efficiency increases, the smaller bandwidths will become more

[1] (https://s3.amazonaws.com/rkfengineering-web/6USC+Report+Release+-+24Jan2018.pdf)

popular. However, all other WLAN deployment assumptions, including the number of high and low activity devices per person, are not changed.

6.2.2.1 No transmit power control

The proposed regulations don't require transmit power control and certainly can't specify the distribution assumed in the RKF study. The regulations can’t require system to comply with any version of the IEEE 802.11 standards either and even those systems often don’t use transmit power control. The transmit power distribution proposed in the RKF study is therefore highly questionable. As an alternative, in order to study the impact of transmit power control, the power distribution shown in Table 3 is also considered and contrasted to the RKF-like results.

EIRP (mW)	1000	250	100	50	13	1
Indoor	90%	2%	2%	2%	2%	2%
Outdoor	90%	2%	2%	2%	2%	2%

Table 3: Additional Power Distributions Considered

In the frequency bands where the regulations don’t allow 1000 mW transmissions, it is assumed these will take place at 250 mW instead.

All other WLAN deployment assumptions, in particular with regards to the bandwidth distribution and number of high and low activity devices per person, are not changed.

6.2.2.2 Increased duty cycle

The proposed regulations don’t contain any restrictions on the duty cycle of the WLAN access points. To evaluate the influence of duty cycle on interference to existing users, an alternative deployment scenario in which high activity devices are assumed to have 5% duty cycle, while low activity devices have a 1% duty cycle, is also considered.

6.2.2.3 Combining no TPC and increased duty cycle

While the previous two alternative deployment scenarios allow evaluation of the relative merits of duty cycle restrictions and transmit power control, neither are currently included in the regulations and a combination of both therefore represents the most realistic deployment assumption.

6.3 Sharing studies

6.3.1 Single interferer

In this section, the effect of the proposed WLAN transmissions on an UWB receiver is evaluated using a minimum coupling loss study. More detailed Monte Carlo simulations are performed in the next sections but in order to perform those an initial appreciation of the interference potential of the WLAN systems is helpful.

The UWB victim is assumed to have a 500 MHz bandwidth, centered on 6.5 GHz. The WLAN system transmits in-band, with an EIRP of either 250 or 1000 mW. The propagation between the two systems is assumed to be free space.

The I/N ratios shown in Figure 1 highlight that the WLAN system interferes over huge distances. An I/N ratio of 0 dB is only reach at a separation distance of 1.3 km for 250 mW and 2.6 km for 1000 mW transmissions. Close up, the I/N ratios at 1 meter separation reach 62 and 68 dB respectively.

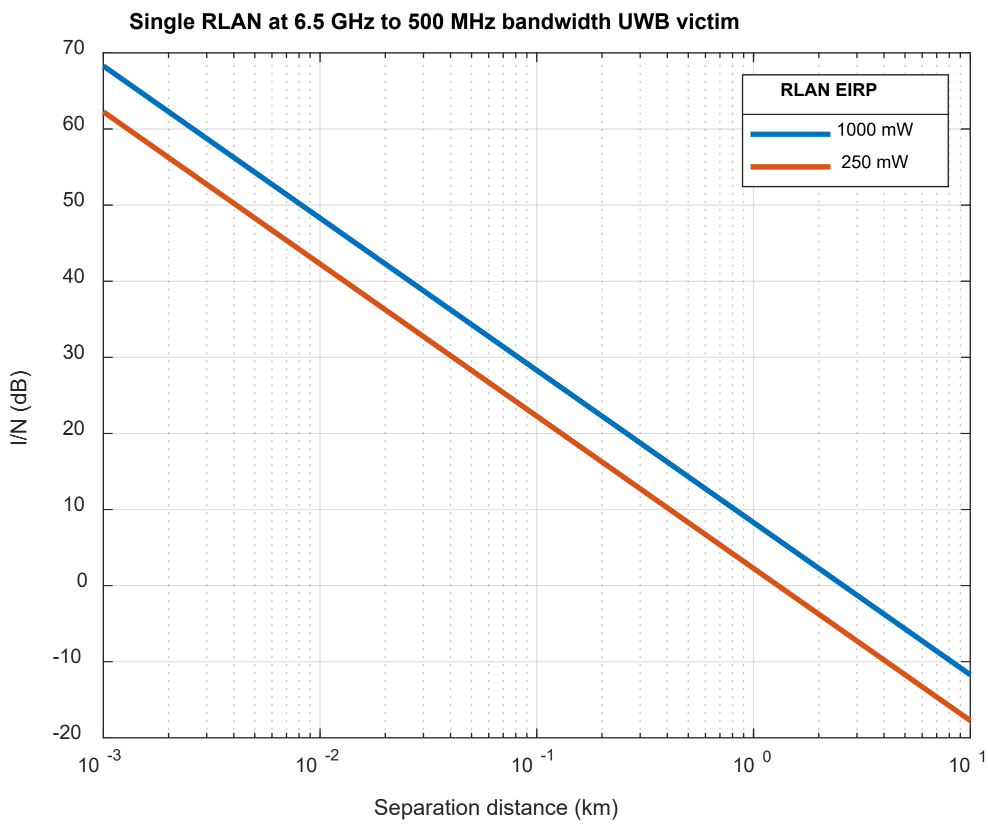

Figure 1: Single RLAN and single UWB victim

6.3.2 Apartment block

In this section, the aggregate interference of WLAN transmitters on UWB systems is evaluated using Monte Carlo simulations for an apartment block scenario.

The individual apartments are assumed to occupy an area of 10 by 8 meters. On average, there are 3 occupants per apartment. The apartment block consists of 10 floors, each 3.5 meters high, with two times ten apartments back to back.

For every iteration, the UWB receiver is randomly located within the building. Similarly, WLAN transmitters are randomly spread throughout the building according to the various deployment assumptions discussed above. The total WLAN interfering power at the UWB receiver is calculated using the indoor path loss model from IEEE 802.11ax channel model B (IEEE 802.11-14/0882r4), as was agreed with the WLAN community within CEPT ECC SE45. Following the model, a wall penetration loss of 5 dB is used. Only WLAN transmitters that overlap with the UWB bandwidth are considered. This conservative assumption implies physically impossible brick-wall filtering in the UWB receiver and infinite out-of-band suppression in the WLAN transmitters.

Every curve in Figure 2 is the result of half a million iterations of the Monte Carlo simulation.

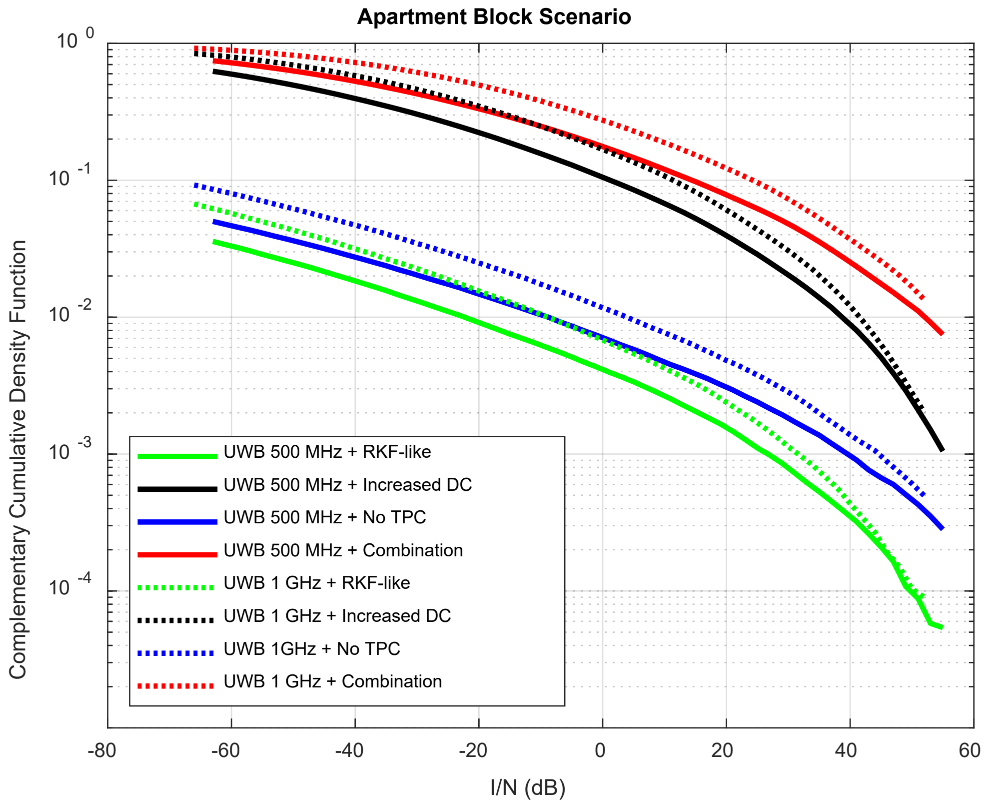

Figure 2: Apartment Block Scenario

I/N (dB)	RKF-like scenario	Increased Duty Cycle	No Transmit Power Control	Combination scenario
-10	0.626%	15.667%	1.044%	24.862%
0	0.416%	10.537%	0.710%	17.662%
10	0.267%	6.776%	0.471%	12.031%
20	0.157%	3.954%	0.309%	7.836%
30	0.079%	2.041%	0.183%	4.814%
40	0.035%	0.889%	0.098%	2.531%

Table 4: Numerical results 500 MHz UWB bandwidth apartment block scenario

I/N (dB)	RKF-like scenario	Increased Duty Cycle	No Transmit Power Control	Combination scenario
-10	1.009%	23.954%	1.679%	36.859%
0	0.652%	16.148%	1.130%	26.539%
10	0.404%	10.232%	0.739%	18.110%
20	0.224%	5.716%	0.463%	11.712%
30	0.105%	2.843%	0.267%	6.869%
40	0.039%	1.079%	0.129%	3.465%

Table 5: Numerical results 1 GHz UWB bandwidth apartment block scenario

Figure 2, Table 4 and Table 5 show that the WLAN transmissions cause significant levels of interference, even under the benign RKF-like deployment assumptions. When the other deployment assumptions, still within the proposed regulatory limits, are used, the interference probability quickly shoots up. In the worst case, without transmit power control and with higher duty cycle, I/N ratios of over 40 dB occur with a probability of more than 2 or 3 percent, depending on the bandwidth considered. To limit the potential of interference, it's crucial that both transmit power control and especially duty cycle constraints are included in the regulations.

6.3.3 London scenario

In this aggregate scenario, it is assumed that an inhabitant of a large urban city is using an UWB receiver. Since population statistics for London are publicly available[2], the characteristics of London will be used.

The results of the single interferer evaluation show that WLAN transmitters located close to the UWB victim receiver are most harmful. Therefore, Monte Carlo simulations are performed with the UWB receiver at the center of a circle with an area of 1 km^2.

WLAN devices are randomly spread throughout the area by combining the population density with the deployment assumptions listed above. Only WLAN transmitters that overlap with the UWB bandwidth are considered. This conservative assumption implies physically impossible brick-wall filtering in the UWB receiver and infinite out-of-band suppression in the WLAN transmitters.

The WLAN devices are distributed in height according to the urban distribution from the RKF study.

The site general path-loss model for propagation between terminals located from below roof-top height to near street level from ITU-R P.1411-9 is used as this has also been agreed with the WLAN community in CEPT ECC SE45. A fifth of the UWB receivers are assumed to be outdoors. As in the RKF study, buildings have 20% probability of being thermally efficient, with a building entry loss of 32.2 dB. Otherwise, the building entry loss is assumed to be 16.7 dB.

The results of the Monte Carlo are shown in Figure 3, Table 6 and Table 7. Five hundred thousand simulations have been performed per curve.

[2] 2017, https://data.london.gov.uk/dataset/london-borough-profiles

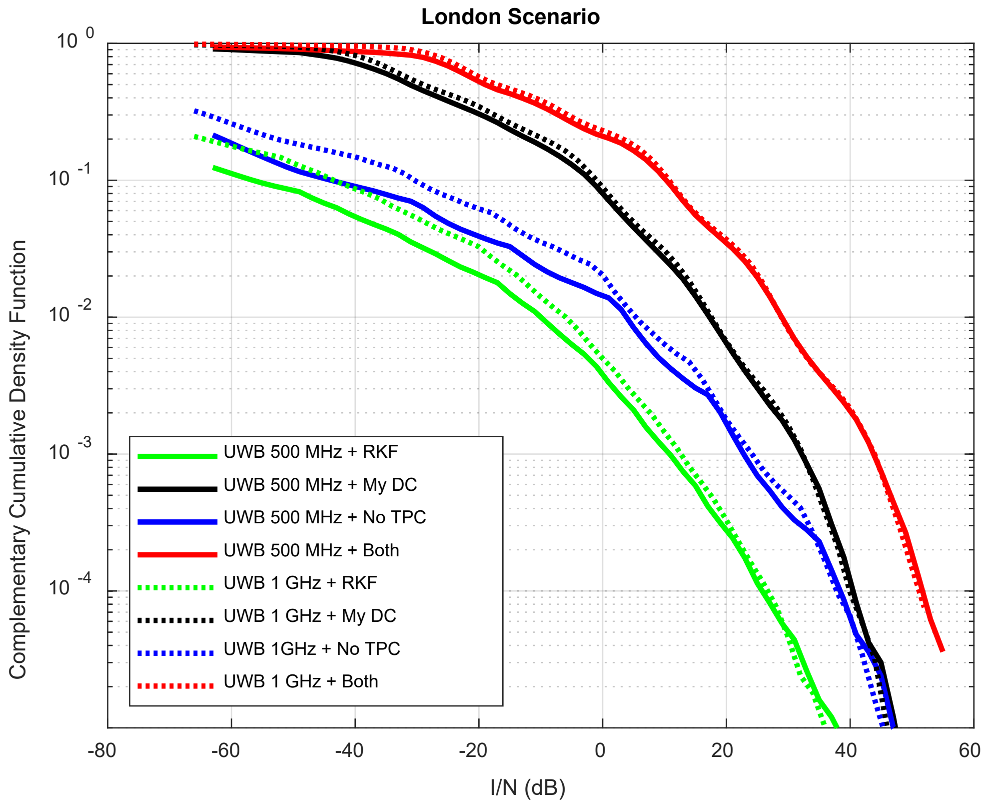

Figure 3: London Scenario

I/N (dB)	RKF-like scenario	Increased Duty Cycle	No Transmit Power Control	Combination scenario
-10	1.006%	18.001%	2.292%	34.919%
0	0.385%	8.067%	1.438%	20.991%
10	0.111%	2.682%	0.465%	10.418%
20	0.028%	0.655%	0.170%	3.497%
30	0.005%	0.152%	0.037%	0.843%
40		0.013%	0.007%	0.209%

Table 6: Numerical results 500 MHz UWB bandwidth London scenario

I/N (dB)	RKF-like scenario	Increased Duty Cycle	No Transmit Power Control	Combination scenario
-10	1.294%	19.523%	3.403%	36.553%
0	0.453%	7.923%	1.781%	22.195%
10	0.128%	2.758%	0.587%	9.750%
20	0.028%	0.578%	0.157%	3.392%
30	0.004%	0.135%	0.045%	0.699%
40		0.008%	0.005%	0.184%

Table 7: Numerical results 1 GHz UWB bandwidth London scenario

Compared to the apartment scenario, the probability of nearby WLAN transmitters is reduced. However, even under the RKF deployment assumptions, there is still a significant amount of interference. The level of interference becomes prohibitive under the other assumptions, again showing the need for duty cycle limitations and transmit power control in the regulations.

6.4 Study Conclusions

The minimum coupling loss study shows that the WLAN device can interfere with UWB receivers over long distances. This is mainly due to the very high difference in transmit power limits between the proposed WLAN devices and the existing UWB regulations.

In the aggregate interference scenarios, in a city or an apartment block, the proposed WLAN limits still lead to interference even under the benign assumptions of the RKF study. Further, these assumptions are based on current applications and duty cycle limits and transmit power control that are not part of the current regulations. Further evaluation shows that these have a huge influence on the interference received and should be included in the rules.

An increase of capacity for all users including Wi-Fi duty cycle at 5% vs 0.5%, no transmit power control, 32% of UWB two-way ranging exchanges will fail.

Given that the 0.5% duty cycle limit exceeds what the proponents used in their RKF study, we suggest this limit is included in the regulations. We propose to define the duty cycle over 1 second intervals. That will maximize the chances for gaps during which UWB transmissions can take place and enable practical verification of the requirement.

Conclusions:

1) Interference is extremely sensitive to duty cycle, and

2) Transmit power control also plays a role and will increase capacity for all users, including Wi-Fi mobile users.

Establishing much lower power levels for APs in mobile and portable devices is a more practical approach to mitigating interference risk while retaining utility.

UWB ALLIANCE

Collectively Creating the Future

Presentation to FCC Office of Engineering and Technology (OET)

February 12, 2019

Who Are We and Why Are We Here?

UWB Alliance – Who are we… *today*?

HYUNDAI

KIA

DENSO
Crafting the Core

Ubisense

Decawave

ZEBRA

XETHRU
BY NOVELDA

alteros
An Audio-Technica Company

iRobot

Why are we here?

- Unlicensed broadband is an expanding essential technology
- So is UWB!

- We have serious concerns about the proposed rules interfering much more than anticipated with consumer, commercial, medical, and scientific applications in the 6 GHz spectrum

- We want to explore opportunities for mutual co-existence

UWB – innovative and unique

- UWB radio offers advantages over carrier-based transmission technologies (Wi-Fi/Bluetooth/etc.)
  - Field proven coexistence with current 6-7 GHz users
  - Ultra Wide Bandwidth yields extremely precise ranging, tracking and material/object sensing
  - UWB signals and modulations require much less power
    - Allows for multi-year battery operated devices with coin cell
    - Smallest form factor devices (e.g., fits under a shoulder pad or in a football)
  - Instantaneous motion detection for advanced IoT uses
  - Virtually eliminates multipath issues
  - Very low power transmissions provide high device density
  - Highly resistant to hacking and hijacking
  - Real-time full frequency audio for entertainment and gaming
  - **Best suited to support the explosion of IOT devices**

UWB – it’s already big, about to get much bigger

- Consumer UWB devices already exist (Many comply with IEEE 802.15.4)
  - Automotive radar ranging systems
  - Baby, sleep apnea, and pulse monitoring
  - Radars for wall exploration
  - Robotic lawn mower for sale this year
  - Fall monitoring
  - Universal IOT Remote
- Commercial applications of UWB are common
  - Professional audio
  - Sports tracking (NFL)
  - Industrial asset tracking
  - Automotive and industrial production automation
  - Stock animal health and tracking
  - Tank level radar sensing
  - Airport baggage handling
  - Bus and train control and communication
- Many more applications are coming fast
  - IEEE TG4z Enhanced Impulse Radio is the most well attended TG in 802.15 Working Group
  - Highly secure wireless entry fobs for vehicles and home entry
  - Smartphone Ecosystems
    - Watches, Secure automated entry, Fitness trackers, Automated “Follow-me”, Pet tracking, Etc.

Why not just move?

- **No Place To Go**
  - **Most Products certified under Part 15.250**
    - **15.250 allows indoor/outdoor use with no 10 s rule or restrictions as to class of service**
  - **Part 15.250 stops at 7.250 GHz and Can't Go Higher because of Government Use restricted Band**
  - **Some Licensed and Unlicensed Production Wireless Devices have already moved 2 other times and this is the "last stop"**
- Disruption Of Operations Of Installed Base
  - The installed Base is consists of millions of devices which are in daily use – Most centered at 6.5 GHz
  - The threat of change is already damaging business
- Performance Risk:
  - Current Part 15 unlicensed devices are effective and proven to successfully share the 6-7 GHz spectrum with incumbent users
  - Potential bands for UWB (10 GHz?) would have vastly different characteristics
    - As any technical Wi-Fi user knows, 2.4 GHz *does not equal* 5.8 GHz
- Other Concerns
  - Time
    - Successful technology innovation takes time
  - Expense
    - Hundreds of millions of dollars invested to bring Part 15 unlicensed devices to market: relocating is not economically viable
  - Discourages Innovation:
    - Large investments made in 6 GHz UWB: Investment cycle must start all over
    - U-NII based modulations do not allow new innovation to flourish

Coexistence suggestion 1

- Authorize new unlicensed Broadband to 5.925 - 6.1 GHz
  - Exceeds 100+55 MHz mandated by the MOBILE NOW Act
  - Will inspire innovation and conservative use of the available bandwidth
  - Provides open field for incumbent UWB, FSS, FS and Scientific Users

AND

- Specify OOBE to -61 dBm/MHz
  - Proposed NPRM limit is higher than mean UWB transmit power making co-existence impossible across all bands
    - Current NPRM is -27 dBm/MHz while UWB is allowed *intentional* at -41.3dBm/MHz
  - A tight OOBE mask is a key technical tool for maximizing capacity and band sharing

Coexistence suggestions 2

- Restrict duty cycle of each 6 GHz transmitter to 0.5% over a period of 1 s
- Specify lower power levels which will yield more capacity given the high demand for the band
    - What is driving the requirement for these high power levels?

Additional requirements for commercial applications

- Create central AFC which all access points must connect to, require AFC everywhere (all bands, all locations)
- A registered beacon fence device allows commercial users to broadcast a signal that informs access points in their fence area not to transmit or allow transmission.
  - This addresses the problem of AFC with mobile devices
  - It also addresses the hidden node and rogue AP problem
- DAA capability required in all new unlicensed broadband devices

Discussion

We are interested in your thoughts on these proposals

- Further discussions prepared:
  - Coexistence #1 – Authorize Wi-Fi band from 5.925-6.1 GHz
    - Analysis behind -61.3 dBm/MHz OOBE for 5.925-6.1 GHz
  - Coexistence #2 – Duty cycle limitation held to 0.5%
    - Analysis of power limitation/standoff distances to prevent UWB interference
    - Analysis of effect of duty cycle on interference via Monte Carlo simulation

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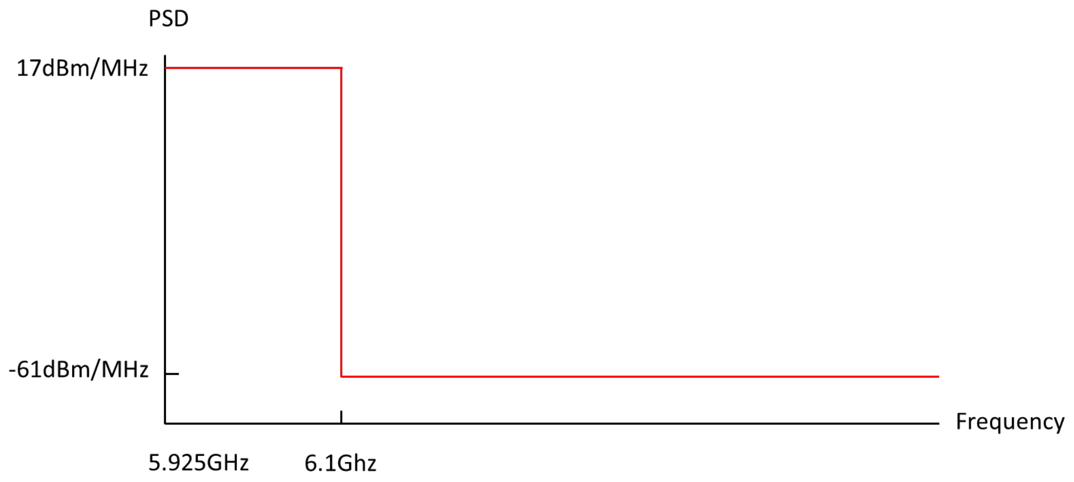
Details on Coexistence Suggestions

Authorizing Top of Band to 6.1 GHz With Tight OOBE

- No duty cycle limit required
- Even with 6.1 GHz limit, -27 dBm OOBE in NPRM results in a loss at victim receiver of 99% at 3 m
- -61 dBm/MHz OOBE PSD recommended for coexistence
- Massive aggregation expected



	UWB Range Loss vs Distance and OOBE PSD EIRP			
Distance to AP (m) -> OOBE PSD (dBm/MHz)	3	5	10	15
-41	74%	59%	33%	19%
-46	56%	37%	15%	8%
-51	35%	18%	6%	3%
-56	16%	7%	2%	1%
-61	6%	2%	1%	0%
-66	2%	1%	0%	0%
-71	1%	0%	0%	0%

Reasoning behind coexistence suggestions

- Start with RKF study assumptions to examine likelihood of interference
- Transmit output power assumptions (by percentage)

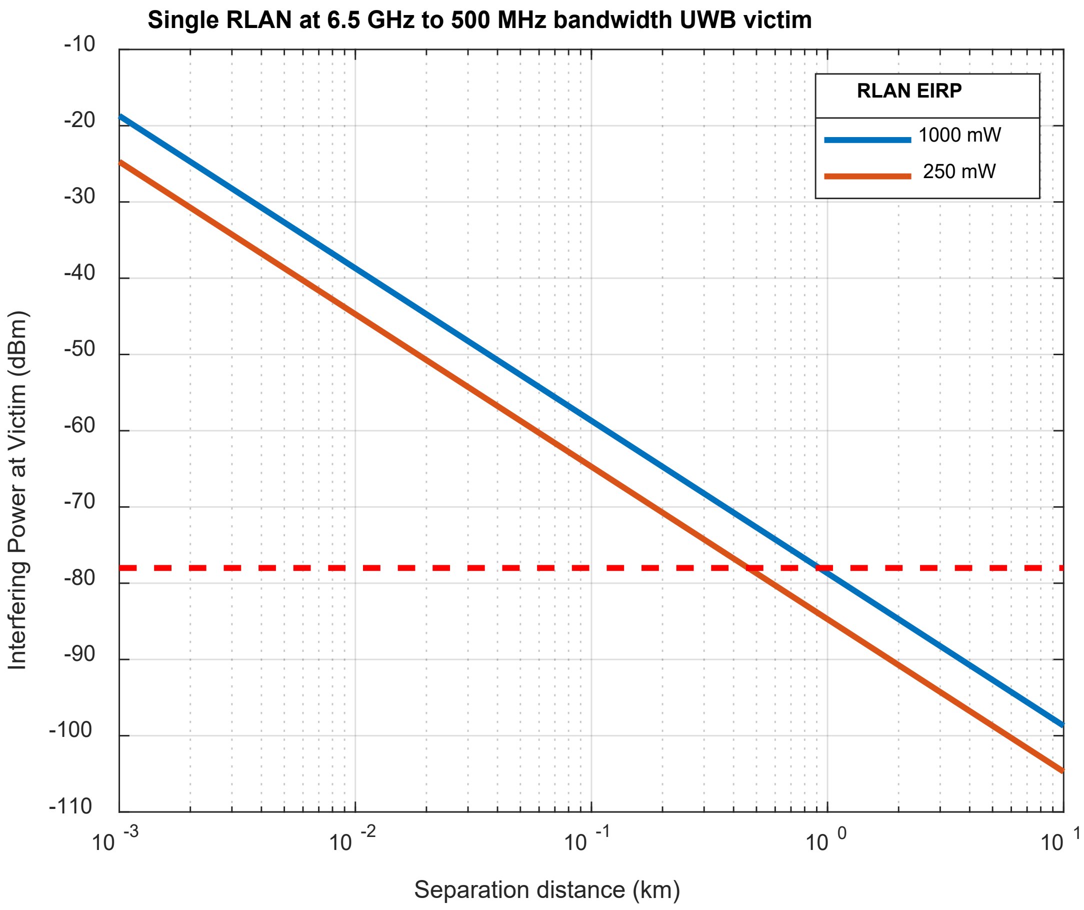
EIRP (mW)	1000	250	100	50	13	1
Indoor	0.67%+042%	10.39%	6.49%	24.64%	51.84%	5.56%
Outdoor	2.83%+2.02%	9.45%	9%	32.13%	41.99%	2.58%

- Duty cycle assumptions:
  - 10 devices per person – one device at 0.44% duty cycle, 9 at 0.00022%

- Changed device adoption assumption
  - 95% 6 GHz enabled because we need confidence beyond 2025 time horizon of RKF study

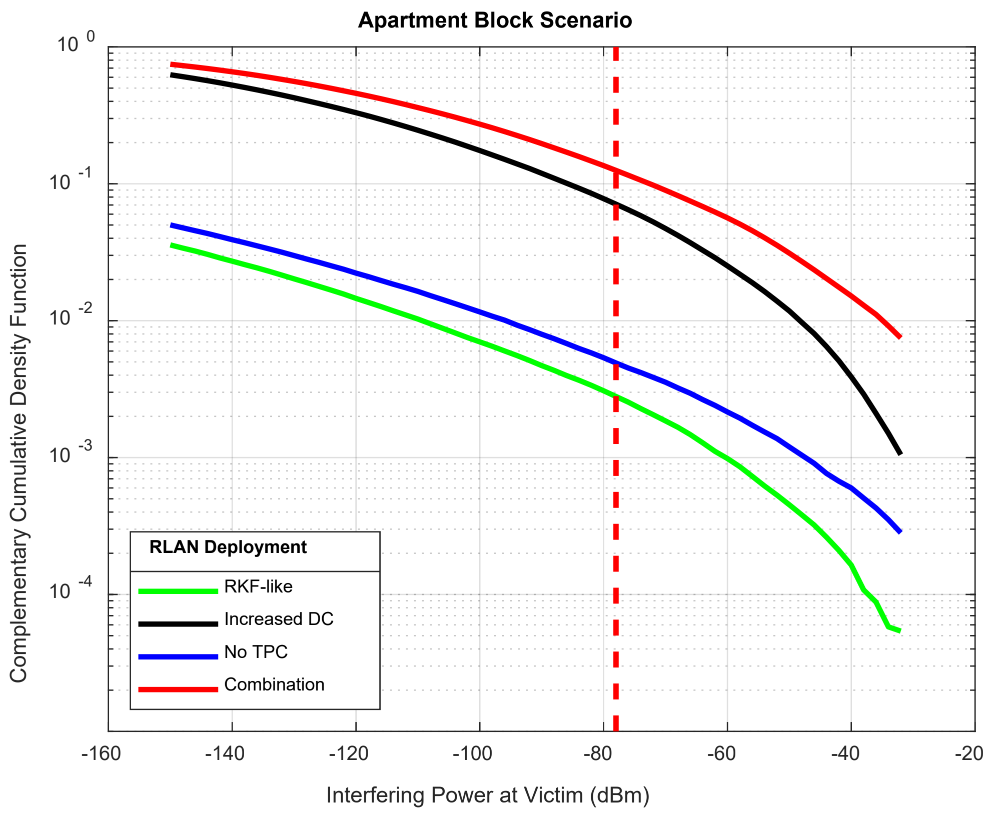
At power levels in NPRM, standoff distances to prevent interference are very large

- Using 3 dB degradation in UWB device performance as tolerable interference threshold
- Need almost 1 km standoff from unlicensed broadband device to allow UWB devices to operate
- Even limiting to 250 mW is a large standoff; power alone can’t solve the problem



RKF assumptions sensitivity study

- Monte Carlo simulation of 6 GHz Wi-Fi deployment in an apartment building
- With duty cycle at 5% vs 0.5%, no transmit power control, **32%** of UWB two-way ranging exchanges will fail



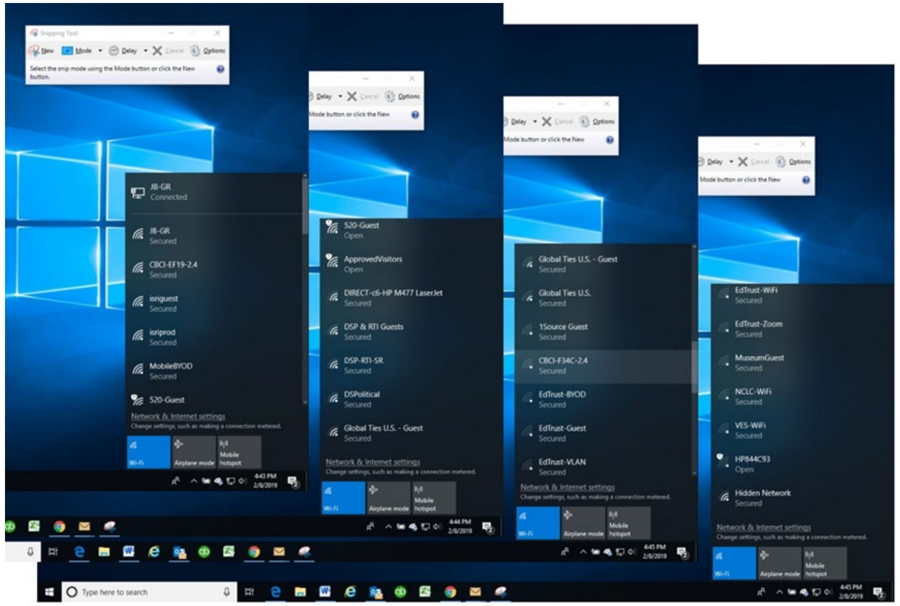
Conclusions:

1) Interference is **extremely** sensitive to duty cycle
2) Transmit power control also plays a role and will increase capacity for all users including Wi-Fi

Assumptions: 95% device adoption by 2025 (higher than initial RKF assumptions), comparing 5% DC to 0.5% DC with TPC and no TPC according to RKF assumptions except using 1 W or 250 mW (not 4 W) max transmit power

Requiring lower power and TPC is a plus for Wi-Fi, UWB, and licensees

- Acknowledging that high power at 6 GHz for rural areas would only be useful for focused point to point links
- Consumer APs typically operate at full power creating congestion, and the need for more bandwidth and power escalation
- Very low power transmissions create less congestion and conserve valuable bandwidth
- Smaller cells yield more capacity



# of SSIDs visible for connection in a typical office on H Street, Washington, DC

Commercial Considerations (Beacon Fence)

- Lower power, duty cycle + TPC can protect consumer devices if they are tolerant to some dropped packets
- Real time audio users of 6 GHz spectrum cannot tolerate this level of dropped packets
- Commercial applications have the benefit of either fixed or mobile but temporarily fixed use
- An RF beacon fence can provide the solution here
  - Beacon is a registered device that broadcasts via already used control frequencies (for easy/cost effective deployment)
  - DAA technology must be required in 6 GHz Wi-Fi devices to prevent transmitting if the beacon signal is received

Thank You For Your Attention

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